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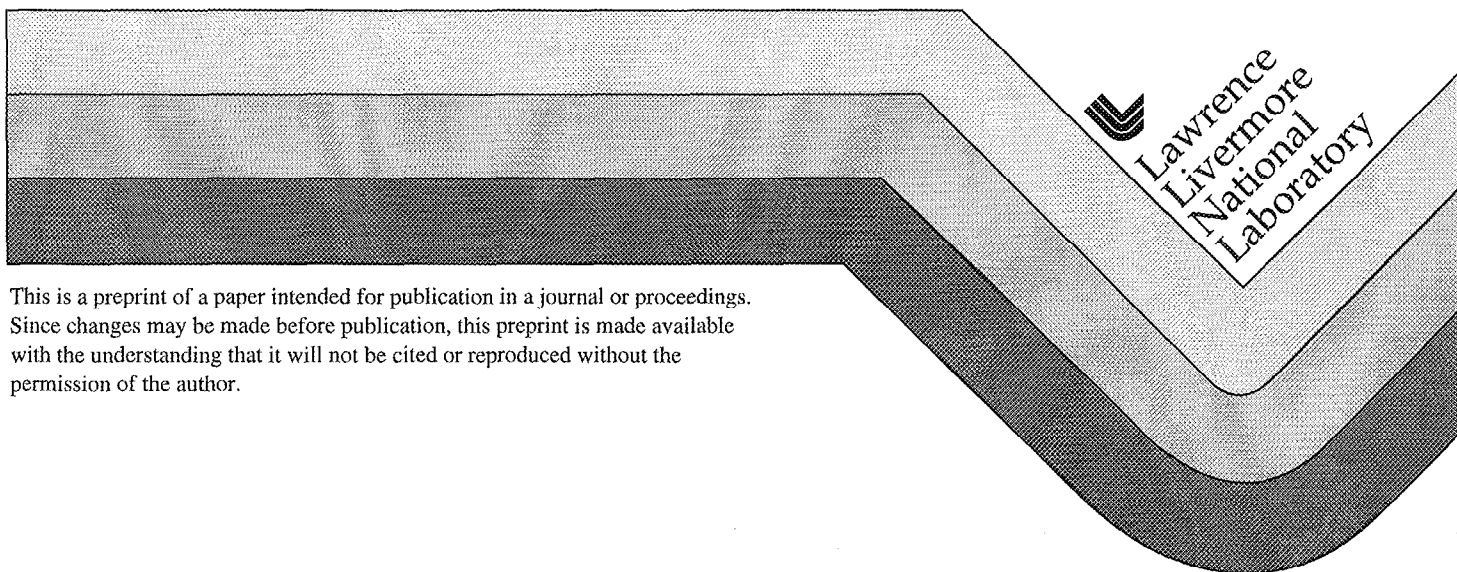
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This paper was prepared for submittal to the
BL Lac Phenomenon Conference
Turku, Finland
June 22-26, 1998

June 1, 1998



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Four New BL Lac Surveys: Sampling New Populations

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Abstract. The advent of large area deep radio and X-ray surveys is leading to the creation of many new BL Lac samples. In particular, the ROSAT All-Sky, Green Bank and FIRST surveys are proving to be rich sources of new BL Lacs. We will discuss the methods used in four independent BL Lac searches based on these surveys. Comparison of the broadband spectral energy distributions of these BL Lacs with those of previously known objects clearly points to the existence of a large previously unrecognized population of objects with characteristics intermediate between those exhibited by Low and High energy peaked BL Lacs.

1. Introduction

The two best-studied samples of BL Lacs are the Einstein Extended Medium Sensitivity X-ray and the 1 Jy radio samples (Stocke et al. 1991; Stickel et al. 1991). However, numerous others exist including the Einstein Slew, HEAO, EXOSAT, S4 and PG samples (Perlman et al. 1996; Wood et al. 1984; Giommi et al. 1991, Kühr & Schmidt 1990, Fleming et al. 1993) in addition to new samples based on the ROSAT All-Sky Survey (RASS; see, e.g., Beckmann et al., this proceedings). With so many existing samples, why are more required? First, despite

these attempts only ~ 250 BL Lacs were known in 1990, and the largest complete samples consist of only ~ 30 objects. Second, these objects were chosen with a variety of selection methods some of which have biased previous samples against particular BL Lac subclasses. New samples which incorporate our current understanding of the underlying physics which drives the BL Lac phenomenon and its effects on observable quantities are required if we are to understand in detail the relationships between BL Lacs and other AGN or between the different BL Lac subclasses. Third, previous surveys have only sampled the brightest objects in either the X-ray or radio bands which has lead to gaps of two orders of magnitude between, e.g., the radio fluxes of sources in radio- and X-ray-selected samples. Interesting populations of objects lurk between the extremes of radio- and X-ray-dominated objects and discovery of them requires delving into fainter populations. Finally, only now are suitable parent surveys available which will allow us to satisfy these goals.

X-ray surveys contain relatively large fractions of BL Lacs. Coupled with the fact that radio-silent BL Lacs either do not exist or are exceedingly rare (Stocke et al. 1990), correlation of X-ray and radio surveys is an efficient means of creating new BL Lac samples. Therefore, we have chosen the ROSAT All-Sky Survey (RASS), the 6 cm Green Bank radio (Gregory et al. 1996) and FIRST 20 cm surveys (Becker et al. 1995) for our parent surveys.

2. RASS-Green Bank

The RGB sample consists of 1567 sources found in a correlation of the RASS and Green Bank catalogs. Optical spectroscopy of previously unidentified objects revealed 38 new BL Lacs (Laurent-Muehleisen et al. 1998) and resulted in a final sample of 125 RGB BL Lacs. These objects span a large range in radio ($3 < S_r < 2160$ mJy), optical ($13.3 < B < 21.2$) and X-ray ($3 \times 10^{-13} < F_x < 4 \times 10^{-10}$ erg s $^{-1}$ cm $^{-2}$) fluxes. Optical polarimetry shows that $\sim 60\%$ of the sources are polarized $> 3\%$ (Pursimo et al., this proceedings). The RGB Complete sample consists of 32 BL Lacs with $B \leq 18.0$ mag in a 3970 deg 2 region of sky. Figures 1 and 2 show the broadband spectral energy distribution of the RGB BL Lacs. These figures clearly indicate that intermediate BL Lacs, those between the previously disparate classes of Low and High energy peaked BL Lacs (LBLs and HBLs, respectively) are present in large numbers and that no clear division exists between the two subclasses (see also Siebert et al., this proceedings).

3. RASS-FIRST

The biggest advantage the RASS-FIRST correlation has compared to the RGB survey is its twenty times deeper radio flux limit which enables the study of lower radio luminosity sources and also moderate luminosity sources to higher redshifts. This facilitates a better study of the effects of cosmic evolution vs. beaming on BL Lac LogN-LogS distributions and luminosity functions. The RASS-FIRST sample currently consists of 82 BL Lacs in a 3000 deg 2 region of the sky. Spectroscopic identifications are continuing but the BL Lacs found to date range from 1 mJy to 1500 mJy and from very low redshift (0.034) to $z=1.37$.

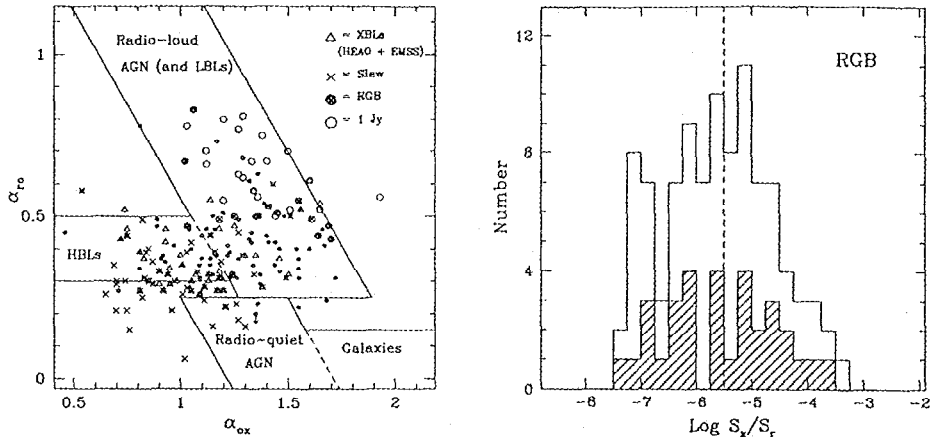


Figure 1. (left) The α_{to} vs. α_{ox} spectral index distribution for the RGB and comparison samples. The RGB sample clearly spans the traditional HBL and LBL regimes in addition to the intermediate region. Figure 2. (right) The distribution of $\log(S_x/S_r)$ for the RGB BL Lacs. The shaded histogram denotes the distribution of RGB Complete sample. The vertical line indicates the canonical HBL/LBL division.

4. FBQS BL Lac Sample

The FIRST Bright Quasar Survey (FBQS; Gregg et al. 1996; White et al. 1998) is a program designed to identify a new deep radio-selected sample of quasars. Spectroscopy of 1202 bright ($R < 17.8$ mag), blue ($B - R < 2.0$) optically unresolved sources has shown that this survey is also a surprisingly rich source of BL Lacs, yielding a sample of 158 objects. The optical color and morphology criteria have undoubtedly biased the sample, but it has the advantage, unlike the RGB or RASS-FIRST samples, of selecting BL Lacs independent of their X-ray emission. It is therefore most similar to the radio-selected 1 Jy sample, but with a flux limit 1000 times more sensitive. This sample will undoubtedly be useful for studying the transition between LBLs and HBLs at radio flux densities between 1 and 1000 mJy, a regime which presently is dominated by X-ray-selected samples.

5. FIRST Flat Spectrum Sample

BL Lacs, like all blazars, exhibit flat radio spectral indices, a fact used to create the 1 Jy BL Lac sample. The high radio flux limit of the 1 Jy sample can easily be improved upon using the FIRST and Green Bank catalogs. We have constructed a sample of ~ 5000 sources with radio spectral indices flatter than 0.5 between 6 and 20 cm and brighter than 35 mJy. We have obtained spectroscopic identifications for $\sim 1/3$ the 1600 sources with counterparts on the POSS I plates and constructed a sample of 68 BL Lacs. Like the FBQS BL Lac sample, the FIRST Flat Spectrum sample is selected completely independent of X-ray emission. This sample will be ideal for studying the transition between Flat Spectrum Radio Quasars and BL Lacs.

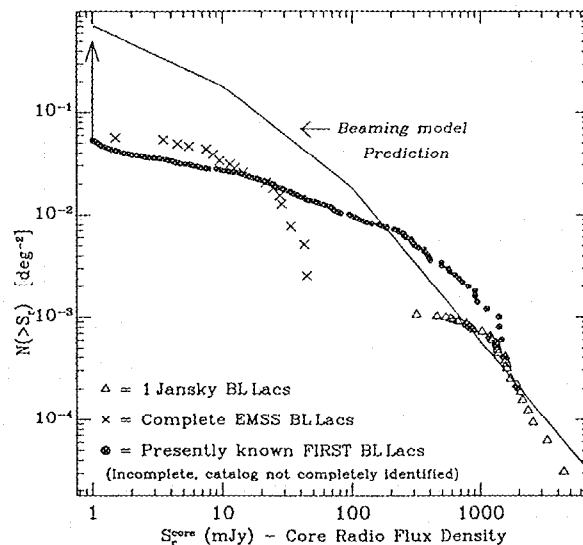


Figure 3. The LogN-LogS distribution for all presently known BL Lacs in the FIRST survey.

6. Summary

New BL Lac samples based on the Green Bank and FIRST radio surveys and the RASS X-ray survey are proving highly successful. In Figure 3 we show the radio LogN-LogS distribution for all known BL Lacs in the FIRST survey (See §3-5). Clearly these samples bridge the gap between HBLs and LBLs and will provide useful databases for constraining unification models and the relationship between BL Lacs and other classes of AGN.

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